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Yield Impact of Irrigation Management Transfer:

Story from the Philippines

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Abstract

Irrigation management transfer is an important strategy among donors and governments to strengthen farmer control over water and irrigation infrastructure. This study seeks to understand whether irrigation management transfer is meeting the promise of its commitments. The authors use data from a survey of 68 irrigator associations and 1,020 farm households in the Philippines to estimate the impact of irrigation management transfer on irrigation association performance and on rice yields. They also estimate a stochastic frontier production function to assess contributions to technical efficiency. There are three main results. First, the presence of irrigation management transfer is associated with an increase in maintenance activities undertaken by irrigation associations. Second, by increasing local control over water delivery, the presence of irrigation management transfer is associated with a 2-6 percent increase in farm yields. Rice production in irrigation management transfer areas is greater even after controlling for various differences among rice farmers in transfer and non-transfer areas. Third, irrigation management transfer is, at a minimum, poverty-neutral, and may even give the asset-poor a small boost in terms of rice yields. The authors speculate that this boost may be a result of increased timeliness of water delivery and better resolution of conflicts related to illegal use.

This paper—a product of the Environment Department—is part of a larger effort in the department to understand the linkages between poverty and environment. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Alexandra Sears, room MC5-206, telephone 202-458-2819, fax 202-522-1735, email address asears@worldbank.org. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at Sbandyopadhyay@worldbank.org or Mxie@worldbank.org. August 2007. (52 pages)

Yield Impact of Irrigation Management Transfer: A Success Story from the Philippines

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1. Introduction

Over the last several decades communities have increasingly sought and won control over the management of natural resources. Developing countries have seen a shift from traditional state control over resources to increased local authority. This trend towards decentralization in resource management is a result of a growing recognition that the state cannot effectively monitor the local uses of natural resources. Simultaneously, it has also become clear that the local communities, under differing circumstances and conditions, are able to cooperate to successfully manage resource use (Ostrom 1990, Baland and Platteau 1996, Agrawal 2001).

While decentralization in resource management is prevalent in several sectors, it is perhaps strongest in irrigation management. This process of transferring irrigation management responsibilities from the government to farmer or irrigator organizations, also known as irrigation management transfer (IMT), first began and expanded in the United States, France, Colombia, and Taiwan during the 1950s through the 1970s. Many developing countries followed this trend in the 1980s and 1990s (Vermillion 1992, Araral 2005). Today, participatory irrigation is an important component of irrigation reform worldwide.

There are many reasons for the increased interest in participatory irrigation. First, irrigation provision has proven to be a large financial burden on national irrigation agencies and exchequers. Cash-strapped irrigation departments, unable to sustain investments in infrastructure, are looking to transfer operational responsibilities to farmers. Further, the possibility of increased floods and droughts from climate change has re-focused attention on water-use efficiency and the need for local scrutiny and control. There is also the general trend towards all forms of decentralization in government functions, which has found support in the irrigation sector.

In practical terms, participatory irrigation has resulted in the growth of a larger number of farmer-run irrigation or water user associations. These associations have taken on numerous functions that were previously the responsibility of national irrigation agencies. This has meant a reduced role for government agencies in operation and maintenance (O&M), fee collection, water management, and conflict resolution.

Though participatory irrigation management is widespread, there is surprisingly little evidence about its impacts (Araral 2005). There are several studies that focus on government savings; however, fewer have sought to quantify impacts on farm productivity or water conservation (see Araral 2005 and Vermillion 1997). A recent exception is a study by Wang et al. (2006), which examines the role of water user associations in influencing water savings in China. They find that monetary incentives to water managers can contribute to water savings; however, these savings do not result in any increase in the incidence of poverty.

The link between irrigation reform and poverty has come under increasing scrutiny. Many critics suggest that irrigation reform has moved away from its original objectives of improving the livelihoods of poor farmers because of its focus on reducing the state's financial burdens (Kloezen et al. 1997; Vermillion 1997; Koppen et al. 2002; Shah et al. 2002). The majority of the world's poor is rural and dependent on farming in one form or the other. Thus, institutional reform in the irrigation sector ultimately has to contribute to the lot of the poor. Thus, far there are few studies that carefully examine this question. There is also little empirical literature on whether there are differential effects of institutional reforms within farming communities.

This paper is motivated by the need to understand the farm level impacts of irrigation management transfer. We try to address three key questions through the paper: a) Is irrigation management transfer associated with improvements in the irrigation system through increased operations and maintenance and better revenue collection? b) Does the increased control farmers have as a result of IMT translate to improvements in crop yield? c) Do these improvements differ for rich and poor farmers? We address these questions through a case study in the Philippines.

We use an econometric approach to answer these questions. We first examine whether the performance of irrigation associations as reflected in operations and maintenance activities changes when management transfer occurs. The hypothesis is that management transfer leads to local control and improves system performance. Second, we look at farm yield impacts. We estimate a Cobb-Douglas production function and examine whether yields are affected by increased local control over water delivery. Third, we estimate a stochastic frontier production function to assess the decrease in overall production in-efficiency. We then look at distributional issues related to yield impacts to understand whether irrigation reforms have a similar effect on rich and poor farmers.

This paper is based on data from a survey of 1020 households and 68 irrigation associations covering the Magat River Integrated Irrigation System, a reservoir irrigation system in the Philippines. The section below first describes the irrigation management system in the Philippines. This is followed by a discussion on methodological issues and data. Results and conclusions follow.

2. Irrigation Management Transfer in the Philippines

In the Philippines, some 50 percent of the irrigation service area is managed publicly under national irrigation systems; another 37% is managed by communal irrigation systems and 13% by private irrigation systems. The national systems are owned and operated by the National Irrigation Administration (NIA), a semi-autonomous government corporation that is responsible for irrigation development. (Sabio and Mendoza 2002, Bagadion 2002).

The Philippines history of organizing farmers to improve production goes back to the late 1960s. However, a more participatory approach to irrigation management was first developed in the mid-1970s for communal systems, and then expanded to national systems in the 1980s. By December 1999, some 2078 IAs operated in nationally owned irrigation systems and 3018 IAs managed communal systems. Overall, these irrigator associations cover 82% of the area developed for irrigation (Mejia 2002).

In the 1990s, irrigation management transfer (IMT) emerged as a new type of contract between irrigation associations and the National Irrigation Administration. This meant that NIA would progressively become a "whole-sale irrigation water manager" for head-works and main systems, while empowered irrigators associations took over responsibility for smaller systems. IMT was actually launched under a World Bank funded project called the Second Irrigation Operations Support Project (IOSP II) and the first IMT contract was signed in 1998 in Magat Integrated Irrigation System. However, the initial IMT conditionality and guidelines under this project were somewhat vague. These were made more concrete and comprehensive program under a second World Bank loan in 1996.[1] There was simultaneously a strong push towards decentralization effort within the Philippines government. In December 1997, the government enacted the Agriculture and Fisheries Modernization Act, which facilitated further devolution in the irrigation sector.

A typical irrigation association has a Board of Directors and Officers. It oversees a variety of irrigation management and infrastructure maintenance related tasks and in some cases offers other services as well. NIA supports the growth and development of these IAs, which can enter into different types of contracts with NIA. An IMT contract,

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[1] Water Resources Development Project.

in particular, transfers operations and maintenance responsibilities of secondary canals or laterals to IAs (World Bank 2001). This transfer in O&M responsibility is accompanied by changes in how water-user fees are obtained from farmers and used by associations. In most cases, the change marks a move to a simple 50-50 sharing of water user fees between IAs and NIA – this money is collected by IAs from members and sent to NIA, which then returns part of the fees.

The motivation behind IMT is that it will reduce government responsibilities for operation and maintenance and simultaneously increase farmer supervision over water-use. This is in line with a broad government strategy to empower communities through decentralization, increase accountability and quality of public sector services, and, streamline the public sector. By lowering government expenditures and strengthening local governance, IMT is expected to have a long-term impact on the country's agricultural and natural resource sectors. Figure 1 summarizes some of the mechanisms through which IMT can be expected to benefit farm households.

First, IMT is expected to increase the control local farmer associations have on irrigation infrastructure and water. For example in a recent survey of 63 IMT contracts in 19 systems across the Philippines provides, association leaders were asked what they liked most about IMT -- the top two reasons were the sense of ownership and control and access to revenues (Hassal and Associates International 2004). With an IMT contract, these associations can make better decisions regarding water delivery and timeliness and can organize themselves to resolve conflicts and maintain infrastructure. Without local control, associations have to wait for the national agency to come in and undertake repairs – with IMT they perform repairs as and when needed.

In terms of revenue generation, an IMT contract makes IAs responsible for collecting user fees from members. The fees are remitted to the National Irrigation Administration, which then sends back a portion. While this process of money transfer is tedious and has resulted in many complaints about NIA, it still increases access to resources by IAs. These resources are critical to the functioning of IAs and enable them to harness members to undertake routine maintenance of canals.

Irrigation management transfer to the extent that it improves the quantity and timeliness of water delivery and reduces uncertainty also affects farm yields. First, there is the direct effect of having water when the farmer needs it. Crops require water at different stages and yields are likely to improve if there is a good match between water delivery and critical growth stages. Second, if the farmer is more certain about water delivery, then this may affect his or her decisions related to other input use. Thus, it is likely to increase the overall efficiency of farm production. This is an issue that we examine in detail in this paper.

Also of interest to us in this paper is the distributional effect of institutional change. Recent literature on decentralization in natural resource management raises the possibility of elite capture, with the rich gaining more than the poor (Adhikari 2003; Klooster 2000a; Klooster 2000b). In an interesting study, Koppen et al. (2002), compare the impacts of irrigation management transfer on poor and non-poor farmers in India and note that interests of the poor do not always overlap with the overall general goals of irrigation schemes. They find that small farmers, who often participate in repair and rehabilitation work, can be unaware of the existence of the water user association, while large farmers involve themselves in committee work and makes decisions. The evidence from Andhra Pradesh and Gujarat, India, points to the strong domination of local elite.

IMT increases local control over water-distribution and can result in localized re-allocation of water – the effect of this on poorer farmers is not clear and will depend on the type of re-allocation done. However, improved matching of farmer needs with water availability could mean that there is more water available in upstream as well as downstream areas. To the extent that the poorer households are located in downstream areas, any improvements in water availability will give them an additional boost.

While the theory on how IMT is supposed to work is reasonably clear and there is some evidence that IMT is beneficial, there are questions globally about whether governments have been too fast in passing on irrigation management responsibilities to local associations (Fujuiie et al. 2005). It is important to carefully examine if ground reality matches the conceptual design of irrigation reforms in the Philippines. Clearly, there are many things that are changed locally when institutional reforms are implemented. There are several levels at which decisions need be made – NIA level, IA level as well as by the farmer and at each stage there may be incentives that work to promote or undermine the change. Thus, whether IMT is good for irrigation in the Philippines is an empirical question and we examine various aspects of this question in the rest of the paper.

IMT in the Philippines is still evolving. Thus, our assessment of IMT is at a point when the program cannot be considered a fully mature program. However, an intervention or reform is never implemented in one-go and there are generally changes over time that are difficult to predict. Thus, we feel that it is reasonable to examine the IMT program in the Philippines in its middle years.

3. Study Area and Descriptive Statistics

Our study was undertaken in the Magat River Integrated Irrigation System (MRIIS) in Region-2, Luzon, of the Philippines. The system is located in the basin of the Magat River, which runs into the Cagayan Valley. It covers 85,294 hectares of service area and encompasses three provinces: Isabella, Quirino and Ifugao.[2] The dams in this system provide year-round irrigation and rice is the major crop grown. Our goal was examine one particular fairly simple reservoir-based irrigation system to understand whether IMT was indeed beneficial to farmers.

Irrigation associations started in MRIIS more than two decades ago. Some of the earliest IAs were registered in 1980 and the number of IAs rapidly expanded during the eighties.

[2] It has four administrative irrigation districts: District III (20,366 hectares) is on the left bank of the river and Districts I (21,797 hectares), II (23,241 hectares) and IV (19,890 hectares) on the right bank.

However, IAs with IMT contracts is a relatively new phenomenon. As of 2003 some 60% of the service area was under IMT contracts. For our study, we collected primary data from 68 irrigation associations or approximately 20% of the 349 IAs in MRIIS. The survey included questions on irrigation infrastructure, service fees, IA or CIA (council of IAs) governance, and system O&M.

We selected a random sample of 43 IAs under IMT contract and 25 IAs that were not under IMT for the survey. Our goal was to carefully examine the IAs with IMT contracts and compare their performance with similar IAs that had yet to sign these contracts. Our sample data shows that 86% of the selected IMT IAs had signed their IMT contract with NIA prior to or during 2001. By the end of 2006, some 68% of the IAs in MRIIS had signed an IMT contract with NIA.

Our study also involved a household survey of 1,020 farm households or approximately 9% of the total IA membership in MRIIS. The households selected for this study were chosen from a master list of IA farmer members from the District Offices. A random sample of 15 farmers was identified from each IA. The survey of IA and farm households was undertaken during May to August of 2003. The survey collected data on various farm level inputs and outputs as well as information on the effects of IMT. Secondary data was obtained on variables such as historical user fee collection from the irrigation district offices.

A simple comparison of IAs with IMT and IAs without IMT along different indicators is presented in Table 1. It shows that both IMT and non-IMT IAs are of approximately the same size in terms of hectares managed. The IMT IAs tend to service a somewhat larger number of farmers and seem to have slightly greater percentage of upstream and midstream farmers. In terms of irrigation infrastructure, the IMT IAs have a slightly larger number of gates, more lined canals and modified infrastructure. These differences are not huge and are logical because IAs tend to get some infrastructure assistance prior to obtaining IMT contracts.

Interestingly there are few obvious differences among IMT and non-IMT IAs in terms of a variety of governance indicators on which we collected data. For instance, there is little difference in the fee collection rate from farmer members or number of female Board members. However, we do find that IMT IAs are better at managing and resolving conflicts from the household data. Households in IMT and non-IMT areas were asked various questions about irrigation water distribution, conflicts and conflict resolution and involvement in maintenance activities. Significantly more households in IMT IAs said that the IAs helped with conflict resolution (see Table 2).

An important objective of transferring management responsibility to IAs is to enable them to take over routine maintenance of irrigation infrastructure. A simple comparison of means shows that this is true of some indicators. A larger percentage of IMT IAs are likely to prepare maintenance plans each year and participate in canal cleaning. There are other indicators of maintenance on which IMT and non-IMT IAs do equally well. A significantly larger percentage of households in IMT areas relative to non-IMT areas said that the water distribution schedule was followed and they participated in routine maintenance activities (Table 2).

Simple mean differences between farm households are reported in Table 2, which shows that about 84% of the sample of farmers has at least a high school degree and some 40% of the households are college educated. There is little difference in education, household assets or livestock between farmers in IMT and non-IMT areas. Farmers in both areas on average farm approximately 2.4 hectares on land in each season. Thus, the average farm is still rather small.

While household characteristics and assets are more or less equal among farmers in IMT and non-IMT areas, there are some interesting differences in farm output. Farmers in IMT areas have on average a 7% higher yield. In the next few sections we follow up on this issue and ask if the higher yield is linked to the presence of IMT.

The survey also asked questions about perceptions of change over the last five years. As Table 2 shows, a larger percentage of farmers in IMT areas said that they had seen improvements in three aspects: a) services provided by IAs or NIA; b) participation of farmers in O&M activities; and c) timeliness of water delivery. In general, the first level analyses of mean differences among households in IMT and non-IMT IAs suggests that households in IMT areas do better in terms of a variety of irrigation related issues.

4. Methods

We try to gauge whether or not IMT is successful is by examining IA performance and by investigating farmer level benefits. There are many methodological challenges to assessing performance and ascribing improvements to IMT, which we discuss below.

4.1. IMT impacts on irrigation association performance

The IMT contract hands over responsibility over canal O&M to IAs. It also specifies that the IAS have to collect membership dues. But does this actually happen? And does it translate to a greater effort at canal re-shaping or improved efficiency in fee collection? More importantly are any observed differences due to IMT or other pre-existing factors? To answer such questions, we consider IAs with IMT contracts and very similar IAs that have yet to sign their contracts and examine their performance.

In order to attribute differences in IA performances to an IMT contract, we have to account for pre-existing differences. We are interested in two outcomes that could be improved as a result of IMT: canal maintenance and fee collection. However, a simple comparison of mean differences in these outcomes does not tell us whether this reflects IMT influence. In particular, some of the pre-existing differences between IAs may have been instrumental to specific IAs being selected for IMT. For example, IAs with more irrigation infrastructure are more likely to join IMT. Similarly, IAs with leaders with better leadership skills may be more likely to join in IMT. In both these cases the factors influencing the participation in IMT are also factors that influence the performance of the IAs.

While various irrigation infrastructures are observable in our data, the leadership skills of IAs leaders are not. These are examples of selection bias based on observable and unobservable data. Assuming unobservable factors are time invariant, correction for both observable and unobservable selection bias in the evaluation of impacts requires before and after intervention data. Without base-line 'before IMT' data, we use cross-sectional data and compute the average treatment on treated (ATT) by comparing IMT IAs with non-IMT IAs. ATT measures the average effect of IMT on the performance (maintenance of canals and fee collection) of those IAs with IMT contrasted with a hypothetical scenario where these IAs do not have IMT.[3]

We estimate the impact of IMT on maintenance and fee collection by using both non-parametric and parametric methods. The non-parametric estimations used to evaluate the performance of irrigation management transfer are based on propensity score matching methods. A propensity score is an index that reflects the probability of an IA having an IMT contract. It is used to match non-IMT IAs (the comparator group) with IMT IAs (the treatment group) on the basis of a set of observed characteristics. Once the two sets are matched, then outcome indicators related to the two groups can be compared. This method is appealing where only cross-sectional data are available to examine program

[3] In impact evaluation jargon, 'treatment' refers to the participation of IAs in IMT and the 'treated' IAs are the IMT-IAs.

impacts and is regarded as one of the best alternatives when random experiment design is not possible (Rubin 1973).

To calculate the propensity score, we model the probability of an IA getting an IMT contract as a function of aggregated household and community characteristics.

$$\Pr(IMT = 1) = \Phi(\alpha_0 + \alpha_1 F + \alpha_2 IA1 + e) \qquad \textbf{(1)}$$

where IMT is an indicator variable that takes the value 1 if an IA is an IMT-IA and 0 otherwise. The probability of an IA becoming an IMT IA depends on factors that influence the ability of IAs to obtain an IMT contract, local conditions, and the process by which IMT reforms were implemented in the Philippines. Thus, our choice of the variables included in **(1)** reflects our understanding of the factors that affect collective action (Agrawal 2001) and our knowledge of conditions that influenced IMT evolution in Magat. Only a handful of studies have attempted to econometrically assess the role of different factors in influencing the behavior of irrigation associations (Bardhan 2000, Meinzen-Dick et al. 2002). Of particular interest is a recent study of irrigator associations in the Philippines by Fujiie et al. (2005), which finds find that collective action in irrigation is influenced by water availability and variability, association size, population density, share of non-farm farmers and the history of irrigated farming. There is no underlying theory that tells us the functional form that **(1)** takes.

In **(1)**, F is a vector of farmer member characteristics and includes aggregate level of education of the head of households, which reflects leadership; percent of catholic households in the IA, an indicator of social norms; the average number of years a household in the IA has been a member of other user groups, reflecting a history of collective action; and average land size in the IA and the number of farmers that are IA members, which are indicators of association size..

IA1 is a vector of irrigation system characteristics such as length of canals, number of head gates, number of duckbills, and other community characteristics such as whether the IA has a post office, and the ratio of IMT-IAs in the municipality. The last variable captures the peer effect of IMT on IA -- an IA in a municipality with relatively more IMT-IAs is likely to be an IMT-IA. In Magat, IMT was implemented under two World Bank funded projects and most IAs that got an IMT contract needed to have some infrastructural improvements made. Thus, controlling for infrastructural differences is very important. All IAs with investments in infrastructure did not, however, get IMT contracts. Our understanding is that only in District 2 all IAs with improved infrastructure received IMT contracts. Staff redundancy concerns within the National Irrigation Administration resulted in some IAs with infrastructural improvements in the other three districts getting the contracts and others not. We try to capture this difference through an indicator variable for District 2. It takes the value 1 when an IA belongs to that irrigation district and zero otherwise.[4]

[4] We tested for more elaborate fixed effect differences between the irrigation districts and rejected the hypotheses. We report only fixed effect of the District 2 in the results section.

The probability function **(1)** allows us to estimate a propensity score for each IA. We then use four different methods to match the IMT IAs with non-IMT IAs: kernel density weighted, radius, nearest neighbor, and stratification method. Each method uses a slightly different approach to match the propensity scores of the two sets of IAs – details of these methods can be found in Abadie et al. (2003) and Imbens (2004).

Once we have matched IMT IAs with non-IMT IAs, we measure the impact of IMT on the irrigation system by examining two outcome indicators: maintenance and irrigation service fees collection. Thus, we arrive at four alternate measures of ATT, each of which estimate the impact of IMT on the IAs as the average difference in maintenance and service fee collection between the matched IMT IA and the non-IMT IAs.

We actually use two measures of maintenance indicators: (i) whether the IAs prepare a maintenance plan every year, (ii) whether canals in the IAs are reshaped/maintained more than twice a year or when needed. The effectiveness of irrigation service fee collection is measured by (iii) collection efficiency in the dry season of 2003 for each IA. Collection efficiency is defined as the ratio of actual collection to the target set by NIA.

An alternate parametric way of estimating the impact of IMT on the irrigation system is to use instrument variable method. For this we model the outcome indicators as a function of IA characteristics described above except the IMT peer effect indicator and include predicted IMT as one of the factors affecting the outcome indicators. The instrument variable, predicted IMT, is modeled as **(1)** above. This allows us to partly control for the fact that IAs choose to undertake IMT contracts and the underlying unobserved characteristics that enable IAs to make this choice may also affect the outcome variables.

Both propensity score matching and instrument variable approaches to impact evaluation have known limitations. The non-parametric, propensity score based estimates of ATT take into account the selection bias from the observable factors such as infrastructure. However, the various methods of matching based on propensity score do not always provide similar results. The parametric estimates of ATT from the instrument variable approach take into account self selection biases from observable and unobservable factors. However, the estimates of ATT depend on the functional form of the model (Ravallion 2001). There is no clear theory that can be applied to identify the functional form used to estimate the determinants of association level outcomes. Thus, various non-parametric and parametric measures of ATT have different strengths and weaknesses. We report estimates based on all the methods to test the robustness of our results.

4.2. Effect of IMT on farm yield

A second important objective of our study is to assess whether IMT has an effect on farm-level outcomes. Our hypothesis is that farm yield improvements are likely to occur in IMT areas because of increased timeliness in water delivery, better distribution of water delivery and decreased water losses due to improved maintenance.

A key analytical question is how to model the impact of IMT on yield. Traditional economic analyses allows for different factors, including technical change, to shift the production function. Thus, one option is to estimate a production function and then allow IMT and household demographic factors to shift production. This strategy assumes that households are fully efficient and produce the maximum possible yield given various inputs. There are many examples of this form of modeling farm household behavior -- one sees this done, for example, in understanding the effect of extension services (Birkhaeuser et al. 1991; Bindlish and Evenson 1997).

However, if we drop the assumption of perfect efficiency in production, then the analytical model changes. Total growth in production can then be viewed to be a result of efficiency improvements and not just increases in input use or technological improvements (Fan 1991). Efficiency gains in production have two aspects: allocative and technical in efficiency. Farmers are considered technically inefficient when they produce less than the maximum output possible given a certain input mix. The idea here is there are differences in farm yields across farmers because of differences in knowledge, institutions and motivations (Fan 1991). Since IMT changes the institutional structure of water management, we can expect it to improve technical efficiency. We assume allocative efficiency since our study area is in one of the most developed rice cultivating regions in the Philippines.

A common empirical problem in estimating production functions is that labor and capital can be endogenous and may vary with un-observed variables that affect yield. This problem of endogeniety has recently led to a focus on cost and profit functions rather than production functions. However, in our case, there was limited variation in farm input and output prices making it impossible to use the dual approach. This is a frequent problem with cross-sectional data and suggests that some care needs to be taken in interpreting results (Barrett et al. 2004).

In this study, we first assume technical efficiency and estimate the impact of IMT on yield. We then test whether IMT contributes to increased technical efficiency of rice production by using the stochastic frontier methodology pioneered by Battese and Coelli (1995).

To estimate the effect of IMT on production, we first start with a simple yield function:

$$y = f(l, m; s)e^{\varepsilon} \qquad \textbf{(2)}$$

where y is yield per hectare, l is the labor used per hectare, m is materials used per hectare, s a vector of factors including IMT that affect yield, and ε an error term.[5]

Demographic heterogeneity of the households and agricultural and irrigation infrastructure may shift the yield function in **(2)**. More importantly, if the IMT results in a more effective water delivery, then that too may shift the yield function. If we assume a Cobb-Douglas production function with constant returns to scale, the yield function together with demographic and IA characteristics may be specified as:

$$\log y = \beta_0 + \beta_2 \log l + \beta_3 \log m + \beta_4 HH + \beta_5 IA2 + \beta_6 IMT + \varepsilon \qquad \textbf{(3)}$$

where y, l, and m are as defined above. HH is a vector of household characteristics such as age of the head, total number of household members, an indicator variable that takes the value 1 if the highest level of education in the household is high school or better and 0 otherwise, an indicator variable that takes the value 1 if the household is not catholic and 0 otherwise, the number of days water takes to reach the household farm, and an indicator variable that takes the value 1 if the household landholding has a drainage canal and 0

[5] One of the reasons we estimate a yield function is because of the way labor is used in rice production in the region. It is the local custom to contract out various labor intensive activities either on the basis of area cultivated or as a share of output harvested. For example, cost of weeding contract may be per hectare rather than wage hours. Similarly costs of harvesting activities were measured as percent of harvested output. Thus, the study does not have an independent measure of labor input and cannot estimate a standard production function.

otherwise. *IA2* is a vector of IA characteristics such as, an indicator variable that takes the value 1 if the IA has an agricultural extension office and 0 otherwise, the number of head gates, the number of modified pipes, and the number of duckbills. IMT takes the value 1 if the IA has an IMT contract or 0 otherwise.

Another methodological concern relates to self-selection. As discussed in the previous section, the selection of IMT-areas may have been based on the community characteristics. Some of the observed characteristics of the IMT and non-IMT areas are similar (Tables 1 and 2). However, there may be other unobserved characteristics of these areas, that may have influenced the selection of an area for IMT and these same unobserved characteristics may also influence the yield of the farmers in the IMT areas. To test this hypothesis, we model the probability of an area being selected for IMT as a function of community characteristics as in **(1)** above and then jointly estimate **(1)** and **(3)**.

Unobservable factors affecting both selection and outcome indicators are a source of concern in any impact evaluation analysis. In this case, IMT participation and agricultural productivity may be influenced by some factor for which there are no data. Thus, such factors cannot be explicitly modeled into the analysis. Let us assume there is such an unobservable factor, say leadership (within NIA or the community), that makes an IA more productive as well as more likely to participate in the IMT. In the presence of this leadership the influence of IMT may appear to be greater on the agricultural yield. Since leadership is unobservable, its effect on **(1)** will be in the residual error term *e*.

Similarly the influence of x on **(3)** will be in the error term ε. To be precise, households in IAs with better leadership will have higher e and higher ε. That is, if there is any selection bias based on unobservable factors the e and ε will be correlated.

To test the hypothesis that unobservable factors affect both **(1)** and **(3)** we jointly estimate the two equations using maximum likelihood estimators and test if the correlation coefficient ρ between the e and ε. equals zero.

4.3. Stochastic Frontier Analyses

Greater control over water a delivery allows the farmer to make better decisions related to farm production. Thus, IMT may contribute to production efficiency. We can test this hypothesis through stochastic frontier analysis. The assumption here is that stochastic inefficiency prevents households from reaching maximum potential yield and demographic and IA heterogeneities affect farm yield via this inefficiency. A detailed exposition of the frontier analysis is found in Kumbhakar and Lovell (2000). To examine stochastic in-efficiency, the production function is re-written as follows:

$$\begin{aligned} \log y = \log f(l, m; s) + v - u \\ v \sim iid\ N\ (0, \sigma_v^2) \\ u \sim N^+(0, \sigma_u^2) \end{aligned} \tag{4}$$

The error term in the production function is assumed to be composed of two components, one component having a symmetric normal distribution v and the other component having a strictly non-negative half-normal distribution u. The error term u represents technical inefficiency and is assumed to be heteroskedastic.

To estimate stochastic in-efficiency, the variance of u for the household is modeled as a function of household demographic and IA characteristics, s.

$$\log \sigma_u^2 = g(s) + \eta \qquad \textbf{(5)}$$

The variables that affect technical in-efficiency in **(5)** include a vector of household characteristics such as age of the head, total number of household members, an indicator variable that takes the value 1 if the highest level of education in the household is high school or better and 0 otherwise, an indicator variable that takes the value 1 if the household is not catholic and 0 otherwise, the number of days water takes to reach the household farm, an indicator variable that takes the value 1 if the household landholding has a drainage canal and 0 otherwise. Also included are a vector of IA characteristics such as, an indicator variable that takes the value 1 if the IA has an agricultural extension office and 0 otherwise, the number of head gates, the number of modified pipes, and the number of duckbills. IMT is hypothesized to reduce technical efficiency. Hence, the coefficient associated with IMT in **(5)** is expected to be negative.

We jointly estimate **(4)** and **(5)** using maximum likelihood estimators. To determine whether the frontier production model is more appropriate than the OLS estimation we test the null hypothesis that $\sigma^2_u = 0$ against the alternate hypothesis $\sigma^2_u > 0$.

The issue of primary interest to us is whether IMT has an impact on yield. To determine the IMT impact on yield, we calculate the average treatment on the treated (ATT). That is, the average increase in yield for all the households in IMT-IAs that may be attributed to the IMT contract is given by:

$$ATT = \frac{1}{N_{IMT}} \sum_{i}^{N_{IMT}} \left[\hat{y}_i (x_i \mid IMT = 1) - \hat{y}_i (x_i \mid IMT = 0) \right] \quad \textbf{(6)}$$

where N_{IMT} is the number of households in the sample from the IMT-IAs and $\hat{y}_i$ is the predicted yield for the *i*th household. IMT=1 refers to the assumption that the IA for the *i*th household is an IMT IA and IMT=0 refers to the assumption that the IA for the *i*th household is a non-IMT IA.

4.4. Rich versus Poor Households

An important motivation for undertaking this study was to assess whether increasing local control over water supply and irrigation facilities IMT had a differential impact on rich versus poor farmers. IMT is rarely set up to help the most vulnerable farmers. Rather, while local responsibility adds to farmers' burden by making them undertaken maintenance activities, it does not always help them with commensurate increases in income. Thus, we were interested in knowing whether local control translates to yield differences among the better off farmers as well as the less better off. Theoretically, if there is elite capture by IA executives, then it is possible that the better-off gain more from IMT rather than the small farmers.

To assess whether rich households benefit more as compared with the poor households, we group the households by the value of household assets. Asset poor households were defined as the bottom two quintile households based on the value of household assets. Separate estimations of the standard yield function as well as the frontier function were computed for asset poor and asset rich groups of households. We test the hypothesis that the respective coefficients for IMT for the two groups are significantly different.

5. Results

5.1. IMT and IA performance

The results of propensity score and instrument variable based methods to understand the impact of IMT on a) development of maintenance plans; b) canal maintenance; and c) irrigation service fee collection are presented in Table 3. We note that there are five different methods in which the impact of IMT on these outcome measures is assessed.

Both the propensity score and instrumental variable approach indicate that IMT is a significant motive for canal maintenance. IMT appears to be the reason for undertaking canal maintenance work in 60 to 80 percent of the IAs that undertake maintenance activities more than twice a season or when needed.

In terms of development maintenance plans, the instrument variable estimator indicates that an IA’s maintenance plan is associated with the presence of IMT 47 percent of the time. However, this strong conclusion is not supported by the four propensity score approaches. The kernel density and nearest neighbor based propensity score matching indicate between 17 to 19 percent of the collection efficiency gains may be associated with the presence of IMT.

All the five different statistical methods suggest that the difference in canal maintenance efforts between IMT IAs and non-IMT IAs is statistically significant and positive. Thus, a significantly higher maintenance effort is associated with IMT and not other underlying factors. These results reinforce some anecdotal evidence that IMT IAs are undertaking more maintenance. On the other hand only two of the statistical methods indicate that higher collection efficiency of irrigation service fees in IMT IAs can be attributed to IMT. Thus, we have less confidence in the collection efficiency indicator of IMT performance.

5.2. Farm Yields

Columns 1 of Table 4 show the OLS estimates of the yield function without the farmer and IA "shift" variables. The material and labor input coefficients are statistically significant. The sum of the two coefficients is less than one as expected.

Column 2 of Table 4 adds the heterogeneity shift variables to the estimation. The input coefficients are similar to those in Column 1. The shift variables where significant have the expected signs. In particular the IMT indicator variable has a positive and significant coefficient. This indicates IMT is associated with significantly higher rice yield productivity. By this measure, about 6 percent of productivity gain is associated with the presence of IMT.

Column 3 of Table 4 shows the results of the instrument variable (IV) estimation of the yield function. The IMT indicator is instrumented by **(1)** into **(3)**. The result is presented in the column 3 of Table 4 and the results of **(1)** are in Table 5. The material and labor input coefficients of the instrument variable estimation for the yield function is close to the OLS estimations in column 1 and 2. As in the OLS estimation in column 3, the coefficient of IMT is statistically significant in the IV estimation.

We note that the correlation coefficient ρ between the error terms of **(1)** and **(3)** in Table 5 is not statistically significant. Thus, the hypothesis that unobserved community characteristics systematically affected the IMT selection process as well as the rice productivity is rejected. In other words we find no evidence of selection bias for IMT from unobserved community characteristics after controlling for community and IA characteristics in Table 5. Thus, we take IMT selection to be exogenous to the household rice productivity estimation.

5.3. Stochastic Frontier Results

The stochastic frontier yield estimations without the heteroskedasticity of the technical efficiency term are presented in column 1 of Table 6. The input coefficients are statistically significant and similar in size and sign as compared with the OLS estimations in Column 1 of Table 4. In Table 6, null hypothesis that $\sigma^2_u = 0$ is rejected at better than 1 percent level of significance. This implies that the difference between the observed rice productivity and the frontier rice productivity is not due to statistical variability alone but also due to technical inefficiency of the households.

Column 2 adds the heteroskedasticity component to the error term associated with the technical inefficiency error term u in the equation **(4)**. The second part of Column 2 shows the estimates of heteroskedastic estimation of **(5)**. The coefficient for IMT in **(5)** is negative and significant at better than 1 percent level. This implies IMT reduces the variability in the technical inefficiency. That is, households in IMT areas would have lower variability in technical inefficiency. Thus, the IMT coefficient in column 2 of Table 6 is not a measure of ATT – it is not directly comparable to the coefficient of IMT in column 2 of Table 4, which is a measure of the impact of IMT on yield. In this case, ATT is calculated from this coefficient using predicted yield, based on **(6)**.

The ATT impact of IMT on rice yield is presented at the bottom row of Table 6. The average increase in yield associated with the presence of IMT for the households in IMT-IAs is 2.2 percent. As expected the estimates of increase in yields using stochastic frontier methods are lower than the increase in yield estimated by the OLS results.

5.4. Rich and Poor

Table 7 shows the OLS estimators of the yield functions for the rich and poor households. IMT appears to have an impact on rice yield for both the rich households, Column (1), and for poor households, Column (2). A 9 percent boost in rice yield for poor households is associated with the presence of IMT whereas the increase in rice yield for rich households is 4 percent. The 5 percent difference in the gain in rice yield for the poor as compared with the rich is statistically significant at 5 percent level. Thus, we find no evidence of elite capture in IMT IAs. The poor households in IMT IAs tend to gain more from IMT as compared with the rich households there.

Table 8 shows the stochastic frontier estimators of the yield functions for the rich and poor households. IMT is a significant negative factor determining the heteroskedasticity of the technical inefficiency in the estimations for both the rich and poor households. The average yield increase attributable to IMT for rich households range between 1.7 percent to 2.1 percent and that for the poor households ranges from 3.4 percent to 5.1 percent. As expected the stochastic frontier estimates are lower than the OLS estimates. The gain in yield attributable to IMT for the poor households is double or more as compared with the gain for the rich households. The relative gain in yield for the poor as compared with the rich are of similar magnitude (double or more) irrespective of the type of estimator (OLS or stochastic frontier).

In order to understand why the poor appear to gain from IMT, we examine some additional questions asked the survey. Table 9 provides information on the how the poor view irrigation water delivery and offers some insights into why the poor may be slightly better off under IMT. A larger percentage of the poor (32%) in IMT IAs are downstream farmers relative to the poor in non-IMT IAs (24%). Further, significantly more of the poor farmers in IMT IAs (relative to poor in non-IMT IAs) indicate that the IAs help resolve illegal use of water. Similarly, significantly more of the IMT IA poor indicate that the water distribution schedule is followed.[6] Thus, one explanation for the boost IMT appears to give the poor lies in the fact that IMT helps increase timeliness of water delivery in general, and, more specifically, downstream availability of water. A recent review of IMT worldwide suggests that one of the ways management transfer can help poor farmers is by increasing the flow of water from upstream to downstream areas (Araral 2005). Our results appear to back this conclusion.

6. Conclusions

Irrigation management transfer is an important strategy among donors and governments to strengthen farmer control over water. IMT is also a means to reduce the financial burdens of fiscally strapped national irrigation associations. In this study, we seek to understand if IMT is meeting the promise of its commitments. Our objective is to understand whether IMT contributes to improvements in both irrigation system indicators and in some household indicators.

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[6]T-tests show these differences between asset poor farmers in IMT IAs and non-IMT IAs are statistically significant.

We draw several important conclusions from this analysis. First, the presence of IMT is associated with an increase in maintenance activities undertaken by irrigation associations. While Irrigation Associations with and without IMT contracts both undertake canal maintenance, the frequency of maintenance in IMT IAs is higher.

IMT areas also have higher rice yields to the extent of 2 to 6% relative to non-IMT areas. Rice production in IMT IAs is higher even after we control for various differences among rice farmers in IMT and non-IMT IAs. Our analysis shows that IMT is associated with a reduction in technical inefficiencies in production. Thus, increasing local control over water delivery does appear to help with farm productivity.

IMT is, at a minimum, poverty-neutral, and may even give the asset-poor a boost in terms of rice yields. We speculate that this boost may be related to increased timeliness of water availability and improved conflict resolution related to illegal use and maintenance.

Quantitative impact analyses of interventions such as irrigation management transfer are best done with pre-intervention and post-intervention data. In this study, we do not have base-line information on irrigation and farm yields prior to IMT -- instead we compare farmers affected by the intervention and those who are not. A criticism of this type of study often is that the 'impact' we show could be a result of un-observable variables that we as researchers are unable to capture in our analyses. Thus, these un-observables may allow some farmers or farmer groups to become early adopters of IMT and the IMT 'effect' that we find is simply the effect of these other variables rather than the impact of

IMT itself. Because we do not have data from 'before and after' IMT adoption, we cannot exclude this possibility. However, as our data show, the control and treatment groups that we compare are very homogenous. This is the rice bowl of the country and farming related information is easily available to most farmers. We have also controlled for observables such as infrastructure improvements that an important aspect of government's strategy for allowing IMT contracts. Thus, we do have a degree of confidence that there are improvements in outcomes that are associated with the presence of IMT.

Another limitation of our study is that it is based on farmer and irrigation association member responses rather than any physical measures of irrigation indicators. We do not actually measure or observe differences in maintenance activities or the quality of the infrastructure as a result of these activities. However, there are other types of studies that are better able to do this -- for example by bringing in engineering skills to the evaluation. Combining quantitative social science research such as this with careful qualitative and water research expertise is a good way forward and we understand that some of this is happening in the Philippines.

Irrigation Management Transfer in the Philippines is still evolving. As with any set of reforms, there is a huge gap between the initial vision and the implementation of this vision. In the case of IMT, our discussions with colleagues who are deeply involved with IMT suggest that this gap remains even in 2007, but many implementation problems are being resolved. Thus, it is possible that our study presents initial insights into the potential benefits of a fully evolved IMT program.

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Figure 1: The linkages between IMT, Irrigation Association Activities and Farm Productivity

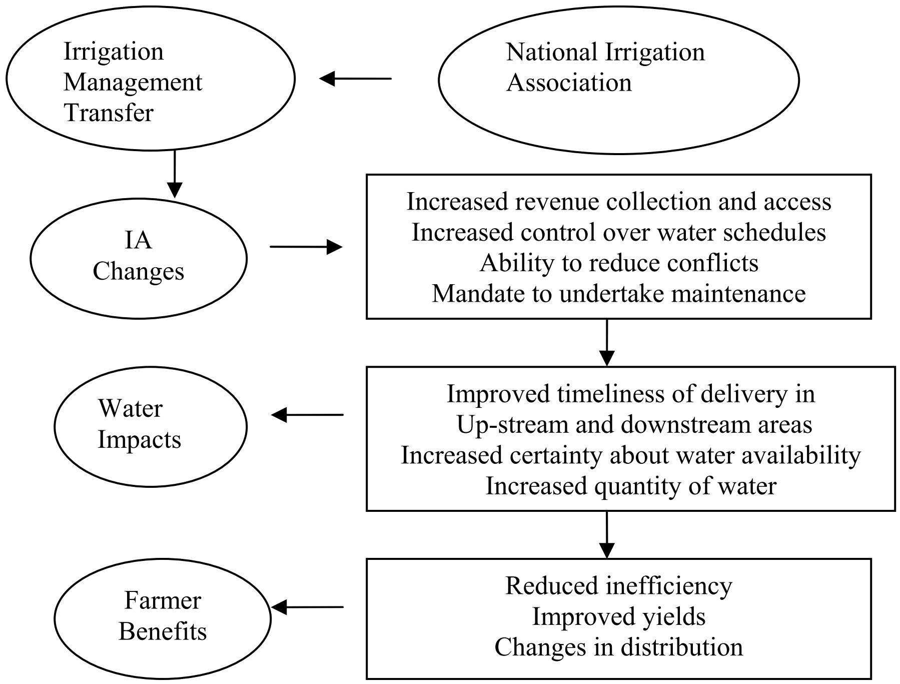

Table 1: Differences between Irrigation Associations in IMT and non-IMT Areas

		Mean	IMT Mean	Non-IMT Mean	Difference in Mean	
	IA Location and Size					
1	Distance from head gate (KM)	5.5	5.9	4.8	1.1	
2	% IA Located Upstream	25.0%	32.6%	12.0%	20.6%	**
3	% IA Located Midstream	30.9%	30.2%	32.0%	-1.8%	
4	% IA Located Downstream	44.1%	37.2%	56.0%	-18.8%	
6	Total area under IA	218	218	219	-1	
7	Farmers IA members	151	165	128	37	**
	IA Infrastructure					
12	Length of lined canal / lateral	0.09	0.14	0.01	0.13	*
15	Number of turnouts	8.1	8.6	7.3	1.4	*
16	Number of modified pipes	1.5	2.0	0.5	1.5	**
	IA Governance					
18	Percent of members paying ISF	65.6%	66.7%	63.5%	3.3%	
21	Number of board members	10.6	11.5	9.2	2.3	***
22	Number of female board members	0.2	0.2	0.2	0.0	
24	% IA involved by NIA in system operational plans	43.0%	42.0%	44.0%	-2.0%	
26	% IA operating gates	47.0%	72.0%	4.0%	68.0%	***
	IA Maintenance					
27	% IA solely responsible for canal maintenance	49.0%	72.0%	8.0%	64.0%	***
28	% IA where NIA and IA are jointly responsible for canal maintenance	16.0%	23.0%	4.0%	19.0%	**
29	% IA Prepare maintenance plan every year	45.6%	62.8%	16.0%	46.8%	***
30	% IA Canal cleaning more than twice a season or when needed	47.1%	62.8%	20.0%	42.8%	***
31	% IA where paid participation is most common	23.5%	32.6%	8.0%	24.6%	***

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based on t-tests.

Table 2: Differences between Households in IMT IAs and non-IMT IAs

		Combined Mean	IMT Mean	NON-IMT Mean	Difference in Mean	
	Household Characteristics (% of households)					
1	Walling materials of house made of concrete blocks	85.00%	85.60%	84.00%	1.60%	
2	Max HH education of HS graduate	19.90%	20.30%	19.20%	1.10%	
3	Max HH Education of College graduate	38.90%	38.60%	39.50%	-0.90%	
4	Average age of household (years)	34	34	34	0	
	Agricultural Output and Input					
5	Output / Ha (Peso)	41823	42512	40638	1875	***
6	Output (Kg) / Ha	5230	5366	4996	369	***
7	Material costs (peso) / Ha	9017	9764	7732	2032	
8	Labor costs (peso) / Ha	11859	11984	11644	340	
9	Area harvested - Palay dry season (Ha)	2.4	2.4	2.3	0	
10	Area harvested - Palay wet season (Ha)	2.4	2.4	2.3	0	
	Livestock, Assets and Protein Food Consumption					
11	Value of Livestock (Peso)	27383	26343	29172	-2829	
12	Value of Assets (Peso)	75778	80381	67862	12519	*
13	Protein Food Cons. Expd (Peso)	830	795	890	-95	
	Irrigation (% yes)					
14	Water distribution schedule followed	71.60%	74.90%	65.90%	9.00%	***
15	Illegal checking sometimes	31.70%	30.40%	33.90%	-3.50%	
16	Never any unscheduled gate opening/closing	56.10%	57.70%	53.30%	4.30%	*
17	IA helps resolve illegal checking	85.00%	87.70%	80.50%	7.20%	***
18	IA helps resolve illegal pumping	84.10%	89.20%	75.30%	13.80%	***
19	IA helps resolve illegal turnout	83.50%	86.90%	78.00%	9.00%	***
20	IA helps resolve unscheduled gate opening/closing	85.80%	88.50%	81.50%	7.00%	***
21	Household often participates in maintenance of main farm ditch	73.00%	75.30%	69.10%	6.30%	**
22	Household often participates in maintenance of sub-laterals	62.00%	64.50%	57.60%	6.90%	**
23	Household often participates in maintenance of laterals	62.40%	65.10%	57.60%	7.50%	***
	Perception of Change in the last five years (% yes)					
24	Improvement in cropping intensity	5.30%	4.80%	6.10%	-1.30%	
26	Improvement in IA services	33.10%	36.60%	27.20%	9.40%	***
27	Improvement in farmer participation in O&M	44.00%	47.00%	38.90%	8.00%	***
28	Improvement in water delivery timeliness	32.10%	34.60%	27.70%	6.80%	**

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based on t-tests.

Table 3: Propensity Score and Instrumental Variable Estimations of the Impact of IMT on Irrigation Association Performance

		Propensity Score Measures of IMT Effect on Outcome								Effect of IMT on Outcome	
		(1)		(2)		(3)		(4)		(5)	
	Outcome	Kernel		Radius		Nearest Neighbor		Stratifi-cation		Instrument Variable	
	Maintenance										
1	Prepare maintenance plan every year	15.4%		23.6%		30.2%		-27.0%		47.8%	**
2	Canal maintenance more than twice a season or when needed	61.5%	***	80.9%	***	62.8%	***	63.7%	***	60.6%	***
	ISF Collection										
4	Collection Efficiency in 2003 dry season	16.9%	**	36.8%		19.0%	**	20.6%		10.4%	

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based on t-tests.

Table 4: IMT Effect on Rice Production

		(1) OLS	(2) OLS with Shift Variables	(2) Instrumental Variable
1	Log of Material costs / Ha	0.072***	0.072**	0.071**
		(0.027)	(0.032)	(0.031)
2	Log of Labor costs / Ha	0.434***	0.440***	0.441***
		(0.041)	(0.045)	(0.045)
3	District:2		0.039**	0.040**
			(0.018)	(0.018)
4	Age of Head		-0.001	-0.001
			(0.000)	(0.000)
5	Total number of household members		0.001	0.001
			(0.003)	(0.003)
6	Max family education HS Grad or above		-0.032**	-0.033**
			(0.014)	(0.014)
7	Non Catholic		0.036**	0.037***
			(0.014)	(0.014)
8	Agri extension office		-0.038	-0.037
			(0.023)	(0.023)
9	Days for water to reach farm		-0.003*	-0.003**
			(0.001)	(0.001)
10	Drainage canal		0.044*	0.044**
			(0.023)	(0.023)
11	Number of head gate		-0.011***	-0.011***
			(0.003)	(0.003)
12	Number of modified pipes		0.000	0.000
			(0.003)	(0.003)
13	Number of duckbill		0.002	0.003
			(0.005)	(0.005)
14	IMT		0.058***	0.053***
			(0.016)	(0.018)
15	Constant	3.847***	3.754***	3.757***
		(0.53)	(0.650)	(0.646)
	Observations	1020	993	993
	R-squared	0.31	0.36	

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based on t-tests.
@ Table 5 presents the second regression used in the instrumental variable approach.

Table 5: Probit regression of IMT on Independent Variables

		Coefficents (SE)
1	District:2	-2.484***
		(0.875)
2	Median edu of head is >= HS Grad	0.912
		(0.814)
3	% sample HH Catholic in IA	-5.249***
		(1.755)
4	Avg Yrs HH member of Other User Groups	0.641***
		(0.171)
5	Avg Land size (ha) per HH in IA	0.853**
		(0.365)
6	Land Gini by IA	2.185
		(1.842)
7	Farmers IA members	0.017***
		(0.005)
8	Length of canal / lateral	-0.493
		(0.450)
9	Number of head gate	-0.566*
		(0.332)
10	Number of modified pipes	0.974***
		(0.251)
11	Number of duckbill	0.378**
		(0.159)
12	IA with post office	0.395
		(0.609)
13	Ratio of IMT-IA in Municipality	12.696***
		(2.628)
14	Constant	-9.368***
		(2.965)
	ρ	0.065
		(0.055)
	Log σ	-1.700***
		(0.057)
	Observations	993

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based in t-tests.

Table 6: Frontier production function and technical efficiency from IMT

	Independent Variables	(1) Full Sample Simple	(2) Full Sample Het σ^2_u
1	Log of Material costs / Ha	0.0570**	0.0467**
		(0.023)	(0.022)
2	Log of Labor costs / Ha	0.395***	0.385***
		(0.038)	(0.037)
3	Constant	4.536***	4.700***
		(0.47)	(0.45)
4	ln σ^2_v	-4.307***	-4.251***
		(0.14)	(0.15)
5	ln σ^2_u		
	Constant	-2.852***	-2.754***
		(0.16)	(0.50)
6	District:2		-0.235
			(0.21)
7	Age of Head		0.00301
			(0.0053)
8	Total number of household members		0.0107
			(0.039)
9	Max family education HS Grad or above		0.409*
			(0.22)
10	Non Catholic		-0.405**
			(0.18)
11	Agricultural extension office		0.212
			(0.26)
12	Days for water to reach farm		0.0339**
			(0.016)
13	Drainage canal		-0.401
			(0.26)
14	Number of head gates		0.0766
			(0.052)
15	Number of modified pipes		-0.00112
			(0.022)
16	Number of duckbills		0.0182
			(0.041)
17	IMT		-0.787***
			(0.18)
	Observations	1020	993
	ATT		**2.2%*** **

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based in t-tests.

Table 7: IMT Effect on Rice Production – Poor and Rich Differences

Sl. N.	Independent Variables	(1) Asset Rich	(2) Asset Poor
1	Log of Material costs / Ha	0.050	0.095**
		(0.037)	(0.047)
2	Log of Labor costs / Ha	0.378***	0.551***
		(0.048)	(0.085)
3	District:2	0.044***	0.036
		(0.016)	(0.030)
4	Age of Head	-0.000	-0.001
		(0.000)	(0.001)
5	Total number of household members	0.001	-0.001
		(0.005)	(0.005)
6	Max family education HS Grad or above	-0.025	-0.041*
		(0.026)	(0.024)
7	Non Catholic	0.034**	0.045
		(0.014)	(0.027)
8	Agri extension office	-0.034	-0.049
		(0.034)	(0.033)
9	Days for water to reach farm	-0.002	-0.003
		(0.002)	(0.003)
10	Drainage canal	0.030	0.059**
		(0.028)	(0.027)
11	Number of head gate	-0.010**	-0.011**
		(0.004)	(0.005)
12	Number of modified pipes	0.002	-0.003
		(0.002)	(0.004)
13	Number of duckbill	-0.001	0.006
		(0.005)	(0.006)
14	IMT	0.036**	0.089***
		(0.016)	(0.026)
15	Constant	4.548***	2.503**
		(0.684)	(1.130)
	Observations	592	401
	R-squared	0.32	0.42

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based in t-tests.

Table 8: Frontier production function for asset rich and asset poor

Independent Variables	(1) Asset Rich	(2) Asset Poor
Log of Material costs / Ha	0.0337	0.0607**
	(0.034)	(0.025)
Log of Labor costs / Ha	0.353***	0.441***
	(0.050)	(0.049)
Constant	5.120***	4.024***
	(0.66)	(0.54)
ln σ^2_v	-4.268***	-4.066***
	(0.18)	(0.38)
ln σ^2_u		
Constant	-2.829***	-3.369**
	(0.67)	(1.52)
District:2	-0.565**	0.236
	(0.26)	(0.38)
Age of Head	-0.00186	0.0112
	(0.0074)	(0.012)
Total number of household members	0.0318	0.00688
	(0.052)	(0.072)
Max family education HS Grad or above	0.280	0.574
	(0.31)	(0.62)
Non Catholic	-0.479**	-0.436
	(0.23)	(0.38)
Agricultural extension office	0.454	-0.0377
	(0.39)	(0.37)
Days for water to reach farm	0.0263	0.0530*
	(0.018)	(0.031)
Drainage canal	-0.143	-0.478
	(0.27)	(0.43)
Number of head gates	0.116	0.00169
	(0.079)	(0.089)
Number of modified pipes	-0.0529*	0.0417
	(0.031)	(0.046)
Number of duckbills	0.0201	0.0225
	(0.053)	(0.071)
IMT	-0.596***	-1.132**
	(0.23)	(0.52)
Observations	592	401
ATT	**1.7%*** **	**3.4%*** **

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based in t-tests.

Table 9: Differences in perceptions about irrigation water delivery among asset poor in IMT and non-IMT areas

	Questions Regarding Timeliness of Water Delivery and Conflict Resolution	Percent of Asset Poor who said Yes			
		Total	IMT IA	NON-IMT IA	Difference
1	Is the water distribution schedule followed?	71.1%	75.3%	63.8%	11.5%***
2	Does the IA help resolve illegal checking?	84.2%	88.7%	77.1%	11.7%***
3	Does the IA help resolve illegal pumping?	84.9%	92.2%	73.4%	18.7%***
4	Does the IA help resolve illegal turnout?	84.4%	89.7%	76.3%	13.3%***
5	Does the IA help resolve unscheduled gate opening/closing?	87.1%	90.9%	81.9%	9.0%**
6	Is your farm located downstream?	29.4%	32.4%	24.2%	8.3%**
7	Do you get water when needed during the dry season?	65.4%	70.9%	55.7%	15.2%***
8	Do you get water when needed during the wet season?	95.6%	96.1%	94.6%	1.5%
9	Did you pay your irrigation service fees twice in the last two seasons?	90.7%	92.7%	87.2%	5.4%**

Note: *** p<0.01, ** p<0.05, * p<0.1. Significance levels based in t-tests.

Table 1A: Instrument Variable coefficients of Impact Evaluation

COEFFICIENT	(1) Prepare maintenance plan every year	(2) IMT	(3) Canal Reshaping/ maintenance >2 a season or when need	(4) IMT	(5) Collection Efficiency 03 Dry	(6) IMT
District:2	0.157	-2.490***	0.166	-2.490***	-0.0454	-2.490**
	(0.12)	(0.83)	(0.13)	(0.90)	(0.076)	(0.98)
Median edu of head is >= HS Grad	0.0170	0.903	0.0670	0.903	-0.220	0.903
	(0.12)	(0.80)	(0.12)	(0.82)	(0.16)	(1.22)
Percent Catholic	0.0256	-5.301***	0.441*	-5.301***	0.123	-5.301
	(0.28)	(1.87)	(0.25)	(1.70)	(0.39)	(3.23)
Avg Yrs HH member of Other User	0.00370	0.643***	-0.0643**	0.643***	-0.0172	0.643**
	(0.033)	(0.17)	(0.031)	(0.17)	(0.022)	(0.32)
Avg Land size (ha) per HH in IA	-0.0912*	0.851**	-0.0553	0.851**	0.0460	0.851***
	(0.050)	(0.37)	(0.053)	(0.39)	(0.034)	(0.31)
Land Gini by IA	-0.400	2.135	-0.764*	2.135	-0.569	2.135
	(0.53)	(2.08)	(0.43)	(1.71)	(0.59)	(2.73)
Farmers IA members	0.0000746	0.0168***	-0.00149***	0.0168***	-0.000389	0.0168***
	(0.00072)	(0.0057)	(0.00056)	(0.0055)	(0.00064)	(0.0053)
Length of canal / lateral	0.120**	-0.472	-0.0435	-0.472	0.0881***	-0.472
	(0.054)	(0.47)	(0.051)	(0.46)	(0.030)	(0.50)
Number of head gate	0.0428	-0.565	-0.0334	-0.565	-0.0152	-0.565
	(0.040)	(0.40)	(0.044)	(0.38)	(0.024)	(0.38)
Number of modified pipes	0.00776	0.976***	-0.00276	0.976***	0.0120	0.976***
	(0.017)	(0.26)	(0.014)	(0.23)	(0.0087)	(0.20)
Number of duckbill	0.0264	0.385**	0.0333	0.385**	0.00246	0.385**
	(0.030)	(0.17)	(0.026)	(0.16)	(0.022)	(0.16)
IA with post office	-0.0786	0.420	-0.0954	0.420	-0.0749	0.420
	(0.13)	(0.60)	(0.10)	(0.62)	(0.12)	(1.12)
IA with IMT Contract	0.478**		0.606***		0.104	
	(0.20)		(0.15)		(0.35)	
Ratio of IMT-IA in Municipality		12.77***		12.77***		12.77
		(2.73)		(2.55)		(0)
Constant	-0.0315	-9.454***	0.891***	-9.454***	0.681***	-9.454***
	(0.33)	(3.04)	(0.26)	(3.12)	(0.24)	(2.33)
Observations	67	67	67	67	66	66

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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